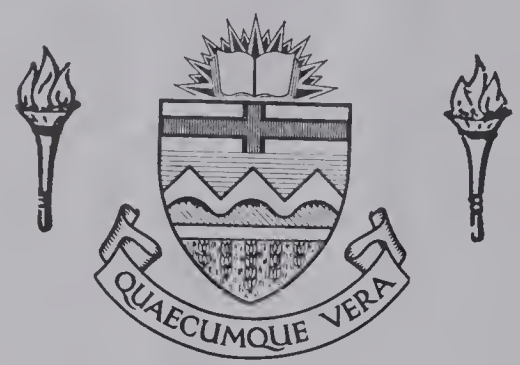


*The University of Alberta*
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# THE EFFECT OF TWO DENSITY RATIOS AND TWO BACKGROUND RATIOS ON THE VISUAL SEARCH PERFORMANCE OF TWO ACHIEVEMENT GROUPS

by

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A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled, "The Effect of Two Density Ratios and Two Background Ratios on the Visual Search Performance of Two Achievement Groups," submitted by Edmund James Welland in partial fulfilment of the requirements for the degree of Master of Science.

# ABSTRACT

The purpose of this exploratory study was to investigate the effect of two density ratios and two background ratios on the visual search performance of two achievement groups. In particular, the area of interest was the possible existence of qualitative as well as quantitative differences in the visual search performance between two groups under four experimental conditions. Visual search performance was considered from both speed and accuracy parameters. A visual search task and apparatus were constructed as a means of testing the visual search behavior of the subjects. Each subject received twenty trials, five under each of the four experimental conditions.

The above average achievement group consisted of eight randomly selected students enrolled in an enrichment class at Prince Rupert School in Edmonton. The below average achievement group consisted of eight randomly selected subjects enrolled in the Winnifred Stewart School for Retarded Children.

The data was processed by ANOVA 80, a Fortran IV program for an n way analysis of variance. From the results of the analysis performed on this data, it was concluded that qualitative as well as quantitative differences existed between the visual search performances of the two groups. The effect of an increased density ratio was a greater decrement in the search performance of the below average achievement group than the above average achievement group. In addition, it was concluded that the increased density of the visual search array caused a decrement

in both the speed and accuracy parameters of performance of the below average group. The performance of the above average group only varied along the speed parameter of performance.

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# CHAPTER I

# STATEMENT OF THE PROBLEM

## Introduction

Several theoretical models have been devised to assist in explaining the various processes involved in human performance. Broadbent (1958) and Fitts and Posner (1967) have proposed models and/or theories to explain related phenomena such as attention, memory, and learning. In general, the models consist of three major components; input, processing, and output.

The first component, input, encompasses the securing and selection of ambient information. The capacity of the sense organs to receive information is astronomically large. The organism is limited, however, in its ability to process the input. While there is no theoretical limit which would apply to all tasks, Fitts and Posner (1967) suggest that practical limits exist specific to the input received and the output required. This limit could be expressed as a maximum amount of information per unit of time.

During the performance of a skill, a complex interaction takes place between the performer and the environment. The skilled performer has developed a method whereby he can handle the informational input efficiently to achieve the desired goal.

Broadbent (1958) and Sokolov (1963) have proposed the existence of a system or process of filtering the informational input to allow the most efficient use of the processing mechanism. The selection or

filtering of input will have a direct bearing on the output. Simple random selection of available input does not seem compatible with the highly skilled performances of the human organism. The selection of input must follow an organized system, whereby relevant information can determine output, while irrelevant information can be effectively rejected.

Performance on a visual search task would seem to emphasize the functioning of the input processes, in particular, the selection of relevant items and the filtering out or rejection of irrelevant items. The use of a visual search task allows the experimenter to control the density (numerosity) and background (similarity) of the ambient symbols. As well, the search task further controls the organizational and dimensional cues available to the viewer.

The scarcity of literature related to the visual search performance of difference achievement groups justifies further study.

## The Problem

The employment of two widely diverse groups based on their present scholastic achievement involved the strong possibility of quantitative differences in visual search performance. The nature of the task which involved cognitive processes (locating the target) as well as motor processes (marking the target) was clearly biased toward the above average performers. The primary purpose of the study was to investigate the possible qualitative differences in the performance of the two groups as influenced by the experimental treatment conditions.

The study investigated the effect of two density ratios (1:5 and 1:25), and two types of background (homogeneous and heterogeneous) on the performance of above and below average scholastic achievement groups.

## Assumptions

The study was organized to compare the input efficiency of the two widely diverse groups. The total test involved all three components of human performance, namely input, processing, and output. The altering of the experimental factors (density and background) was assumed to result in changes only relative to the input operation of the human performer.

It was further assumed that the visual search task employed in the study elicited from the two groups a performance indicative of their ability. To further this assumption, the materials used in the test were selected to reduce possible bias toward either group.

The timing mechanism used for the measurement of one of the performance variables was initiated by the experimenter on each trial. It was assumed that the variations in the experimenter's reaction time would not constitute a form of bias toward either group or experimental condition involved in the study.

A final assumption involved the selection of subjects comprising the below average scholastic achievement group. A sample of four mongoloid and four brain damaged children was considered representative of the population of students at the Winnifred Stewart School for Retarded Children.

## Delimitations

The study employed two levels of the three experimental factors. The levels were selected as representative of a high and low level for each factor.

The selection of students representing the two levels of achievement was restricted to a chronological age range of nine and one-half to ten and one-half years of age.

The cues available for discrimination between field objects were restricted to one dimension, shape. Other dimensions such as hue and size were kept constant for all experimental conditions.

## Limitations

The tests were conducted in available rooms at each of the educational institutions involved in the study. The use of a familiar environment was deemed necessary to encourage the best performance of the subjects most notably the below average achievers. This procedure eliminated the uniformity of test environment possible in a laboratory setting.

The investigator initiated the timing mechanism at the start of each trial. The variation of search times for the first target was partially due to fluxuations within the reaction time of the investigator.

The size of the display items and the area of the display were constant for all trials. This results in an increased packing density for experimental conditions involving the higher density ratio.

The study was exploratory in nature, by the fact that the writer

failed to find studies directly related to this area of interest. This fact, plus the methods selected for measuring performance, failed to permit the precise psychological processes involved in the study from being investigated. These processes have been collectively referred to as the input component of human performance.

## Definitions

Achievement Level. The subjects involved in the study were classified on two levels of achievement. Achievement was a factor involving the performance of the subject relative to her chronological peers. The achievement level of the subjects involved in the present study was determined by the educational institutions in which the subjects were enrolled.

Background Ratio. The non-target items were classified as background. A background ratio of one to one consisted of similar non-target items. A background ratio of one to five consisted of an equal number of each of the five non-target items.

Density Ratio. The low density condition consisted of a target to non-target ratio of one to five. The high density condition consisted of a target to non-target ratio of one to twenty-five.

Experimental Conditions. The study involved four experimental conditions. The conditions were derived from all possible combinations of the two levels of density and background factors.

Location Errors. Non-target items marked as target items by the subject.

Non-target. Any of the geometric figures used in the test, with the exception of a square.

Omission Errors. Target items not located by the subject during the duration of a trial.

Packing Density. The proximity of display items was a function of the display area and the number of items present in the display. The visual display area was constant in the present study. Thus, an increase in the density ratio (numerosity) resulted in an increase in the packing density.

Total Performance. The combined performance components of speed and accuracy.

Search Time. The time required by the subject to locate the target items for each trial.

Target. A geometric square.

Total Errors. The sum of the location errors and omission errors.

# CHAPTER II

# REVIEW OF THE LITERATURE

Investigations concerned with the selective processes of attention and perception include a variety of experimental methods. Egreth (1967) divided these investigations into four categories; those dealing with briefly presented visual stimuli (tachistoscopic studies), multiple auditory messages, filtering in speeded classification tasks, and visual search. The present review was limited to those studies concerned with visual search.

One method of evaluating visual search behavior was by measuring the search time or search rate required by the subjects. In a majority of these studies the instructions were manipulated to reduce the occurrence of errors. A second method of evaluating visual search was through the analysis of the eye movements of subjects during search.

The purpose of this review was twofold. It attempted to determine the effect of density (numerosity of symbols) and background (form of the symbols) on visual search behavior. Secondly, the review allowed the investigator to evaluate the different experimental techniques employed in various visual search studies.

## Components of Visual Search

Forsman (1967) described visual search as "a sequential, repetitive discrimination problem performed under a speed demand". Kaplan and Carvellas (1965) described visual search as the comparison of a memory

representation of the target item with the symbols present in the visual field. Kaplan, Carvellas, and Metlay (1966) viewed the three components of visual search as "size of target set,the learning for, or memory of the targets, and properties of the field that may contain those targets". The above descriptions of visual search imply an interaction between the performer, and the field through which the visual search is conducted.

Williams (1966) partitioned the visual search act into two components, identification and acquisition. Identification implied the classification of the foveally imaged objects as a target or non-target item. Acquisition concerned the selection of the point or object outside the fovea on which to fixate next.

## Factors Necessitating Visual Search

Visual search is initiated when information required from a visual display is not immediately available. The speed and ultimate success of the search process for each individual person is determined to a large degree by the environmental factors present in the search field. Gottsdanker (1960) referred to these factors as search determinants. They are as follows:

1. Interposition. The partial or complete blocking of the target symbol from the viewer.

2. Smallness. The relative size of the target symbol as compared to the size of the total display area.

3. Weakness. The relative contrast of the target symbol as compared to that of the total display area.

4. Distortion. The perspective deformation of the target due to orientation of the target; or variations in density of the intervening medium.

5. Inbeddedness. The de-emphasis of target symbol contours by the use of strong inner contours; or the partial sharing of contours of target and non-target symbols.

6. Competition. The discrimination problem involving non-target symbols within the visual display containing the target symbol.

In a situation necessitating visual search, one or more of these determinants exist in the display. The determinant most employed in visual search studies was competition. Competition occurred when the target and non-target symbols shared some common dimensional feature such as colour, shape, or size.

## Visual Search Dimensions

The identification component of visual search involved the discrimination of the target item from the non-target items. Sleight (1952) investigated the discriminability of twenty-one geometric forms. The efficiency of the forms was estimated by the sorting time required for each form. The attention getting value of each form was determined by the order of priority of the subjects' selection. He concluded that the discriminability of a geometric form was not exclusively intrinsic to the form, but an extrinsic quality related to the total situation.

Green and Anderson (1956) used a visual search task to evaluate the effectiveness of colour coding. When the subject knew in advance

the colour of the target, the search time was approximately proportional to the number of symbols with the same colour as the target. The search time was dependent upon the total number of symbols in the display when the subjects were not aware of the targets' colours prior to search. Search times were longer for multicoloured displays than for similar unicoloured displays.

Smith (1962) (1963) used colour dimensions for displays varying in density from 20 to 100 items. The use of colour was related to a significant decrease in search time. Smith failed to find a slower search time related to multicoloured displays than was found by Green and Anderson. Smith (1962) suggested that the projection techniques employed by Green and Anderson in their 1956 study led to a depth perception factor which slowed the search rate.

Eriksen (1952) investigated the effect on search time of the number of dimensions on which the items differed. The dimensions used were hue, form, size, and brightness. Predicted values were calculated using a weighted geometric mean of the location times of the component single dimensions. The single dimension with the smallest mean search time was given a weight of two, and the dimension with the longer search time was given a weight of one. Hue was significantly faster than the remaining three dimensions, and form was significantly faster than brightness and size. The location time for the compound dimensions had a rank correlation of 94 with the predicted means. Compounds which involved the size and form dimensions were considerably higher than the predicted values.

Williams (1966) used an eye fixation measurement technique and

found that in a visual display employing colour, size, and shape as item dimensions, colour was the most effective dimensional cue. When two or three dimensions were available to the subject prior to search, he generally fixated objects based on one of the available dimensions. The order of priority was colour, size, and shape. The efficiency of searching (mean search times) also showed the superiority of colour codes. Mean search times were colour 7.6 seconds, size 16.4 seconds, and shape 20.7 seconds.

## Measurement Involved in Visual Search Studies

The most common dependent variables used in visual search experiments were search time, scanning time, and errors. The task responses in various studies included visual location, pointing responses, verbal responses, card sorting, and item cancellations.

Search time was a measure of the total elapsed time from visual presentation of the display to completion of the identification response. The components involved in total search time were the initial delay at the start of the task, the time spent on the visual search, target recognition time, organization time of the appropriate response, and the response time. The assumption made by investigators using search time as a dependent variable was that the fluctuations in search time due to independent variables such as density and background, would have the greatest effect upon visual search. The manipulating of visual variables should not influence the time involved in motor responses.

Neisser (1963) devised a method to determine the scanning rate

(search rate) for each item of a display. The target position was plotted against the search time and a line was drawn using the least square method. The slope of this line was a measure of the time required to search an individual number. This measure represented a relatively pure measurement of search rate, unaffected by the initial delay and some response factors of the search task.

In a study by Kaplan, Carvellas, and Metlay (1966), the subject was photographed as he searched a display and cancelled the appropriate target items. Search Rate was defined as the elapsed time between successive cancellations divided by the number of non-target items between the cancellations.

The use of search rate as the dependent variable in search tasks necessitated an organized search pattern (line by line) by the subject. This required a visual display so structured to produce this searching technique, and the co-operation of the subjects involved. The use of search time as a dependent variable, while not being as pure a measure, allowed freedom of search strategy by each subject. Studies that involved some form of random placement of symbols, used total search time as a measure of the time parameter.

A third measure of visual search performance was error score. The two types of errors common to visual search experiments were omission errors and commission errors. Neisser and Beller (1965) defined an omission error as the failure to locate a target item. A commission error was defined as an inappropriate response to a non-target item. In several visual search studies, the number of errors committed by the subjects

was relatively few. In these cases the trials where errors occurred were repeated later.

Display Density and Visual Search

From a practical standpoint, it would seem reasonable to assume that the speed of detection of a target would be directly related to the numerosity of non-target items in the same visual display. McGill (1960) used background densities of 24, 48, 72, and 96 in a search task. The display items were three digit numbers randomly placed in an eighteen inch square. The recorded search times were directly related to the number of alternatives (density). An increase in the number of alternatives caused an increase in the search time. The relationship between search time and density was linear.

Green and Anderson (1956) found that the search time was proportional to the total number of items in the display. The subject's prior knowledge of the colour dimension shared by the target item reduced the search time. This reduced search time was proportional to the number of items (density) similar in colour to the target. Studies by Smith (1962) (1963) reported a similar relationship between density and search time.

Neisser (1963) compared the rate of scanning for a target letter over items two letters and six letters in width. The six letter item list took significantly longer to search than the two letter item list. This slower scanning rate was attributed to the larger number of letters (density) through which the search was conducted.

In a subsequent experiment, the search rate for six letter items was compared with four letter items. The four letter items were composed of the spacing of six letters by the use of two dashes between the letters. The longer scanning rate associated with the six letter item list convinced Neisser that the horizontal spread was not the critical factor in search, but rather the number of letters (density) in the display.

## Background Factors and Visual Search

Studies by Neisser (1963), Neisser, Novick, and Lazar (1963), Kaplan and Carvellas (1965), and Kaplan, Carvellas, and Metlay (1966) reported that the subject does not recognize the non-target items at a conscious level. Despite this lack of identification by the subject, the non-target items in a display did affect search performance.

Two relationships involving the background items have been investigated. The first relationship concerns the target and the non-target items. Neisser (1963) found that the relationship between the non-target items and the target items significantly affected the search rate. An angular alphabetic letter took longer to locate when associated with other angular letters than with non-angular or curvilinear letters in the display.

A developmental study of visual search behavior by Gibson and Yonas (1966) used two conditions of background confusion. The target letter was G in both cases. The low confusion background consisted of the angular letters L, K, V, M, X, and A. The high confusion background used the curvilinear letters B, Q, C, J, S, and R. The subjects were

selected from second, fourth and sixth grade students and sophmore university students. A significantly longer search time occurred for curvilinear backgrounds for all age groups involved in the study.

Kaplan, Yonas, and Shurcliff (1966) reported a similar effect of background on visual search. The study employed a high and low level of visual and accoustical confusability. The accoustical confusability was not significant. The visual confusability accounted for a significant difference in the search times of the subjects. The increased difficulty in discriminating between the target and the non-target items resulted in slowed search rates.

A second relationship exists between non-target items. Gordon (1968) investigated the effects of four non-target items acting along (homogeneous background) and then acting in various combinations (heterogeneous background). The target symbol was an "a" and the background symbols used were "b", "c", "d", and "e". The backgrounds used in the study were each letter alone (background ratio of one to one), each possible paired combination (background ratio of one to two), and the four letters (background ratio of one to four). A significant difference was demonstrated between the mean search rates for the three background ratios. The rate of search varied directly with the number of types of background letters present in the display.

A second experiment used nine cell matrices in place of letters as items. Four cells of each matrix were filled with a dot. The non-target matrices had no overlap cells with the target configuration. A third experiment used the same material with the exception of the inclusion

of one overlap cell in each non-target matrix with the target matrix. The analysis of search rates revealed the same effect of background in both experiments. Increased heterogeneity of background slowed search rates. The differences between the condition means for the second and third experiments were not significant. Gordon hypothesized that homogeneity of background allowed a longer saccadic eye movement following a fixation. As background became more heterogeneous, the distance between successive fixations would decrease.

## Eye Movements and Visual Search

Enoch (1960) found evidence that supported a two phase visual search process. The first was an orientation phase which remained relatively stable for each individual subject. The pattern of this initial phase also remained stable for changing content variables. Familiarity of the material in the display was the only variable found that influenced this phase. The effect was that the orientation phase was shortened.

The second phase was a specific search phase. Cues which would aid in location of the object were utilized immediately upon initiation of this phase. During the search task, a marked non-uniformity of coverage was observed. There was a concentration of coverage at the center of the display with less at the peripheral regions. This result was general to most types of displays.

Enoch concluded that the general path of search was controlled by the central nervous system. The individual eye movements within the

general search pattern were dominated by the effects of peripheral retinal stimulation. Records of visual search of aerial photographs and aerial maps showed a high percentage of fixations fell on objects which would be expected to act as strong peripheral stimulation.

In a series of studies where degradation of the display (increased display complexity) was employed, Enoch found that the duration of fixations increased and the interfixation distances decreased. A study by Gould and Schaffer (1965a) investigated the eye-movement pattern during the scanning of numeric displays. A display matrix of 36 cells contained single digit numbers. An increase in target frequency from zero to seven resulted in an increase in the number of fixations. The difference between the average duration of fixations on target and non-target items was not significant. Gould and Schaffer (1965b) increased the complexity of the task by using the sums of three digit numbers as the stimuli. This increase in complexity of the task resulted in an increased duration of fixations. Once again the duration of the fixations on target and non-target items was not significantly different. Gould and Schaffer concluded that changes in the complexity of the visual search task resulted in changes in the duration of fixation rather than changes in the number of fixations.

## Organization of Visual Search Displays

The visual displays employed in visual search studies have varied on several organizational factors. One common organizational design used in visual displays was an organized matrix (horizontal and vertical

arrangement of cells). Gould and Schaffer (1965a), Eriksen (1952), and Promisel (1961) used a matrix with each cell filled with a stimulus object. Green and Anderson (1956) and Smith (1962) (1963) used an organized matrix with random placement of stimuli in some of the cells.

Search studies (Neisser, 1963) employing the measurement of scanning rate used a series of lines which in total perspective was a matrix. Williams (1966) placed the stimulus objects completely randomly within the border of the visual display. A similar display was found in the sorting experiment by Sleight (1952).

A further organizational factor was the orientation of the stimuli within their placement position. Gottsdanker (1960) referred to this factor as an orientation search determinant.

Brody, Corbin and Volkmann (1960) suggested that for specific materials and subjects, a critical display size existed. Below this critical value no search took place. Above the critical value, a wandering or systematic search occurred. For a display containing a triangle target and circular non-target items, the critical matrix size fell between 10,000 and 20,736 square centimeters.

## Developmental Aspects of Visual Search

The cognitive processes and subprocesses operative in visual search tasks have been shown to develop with practice on specific tasks. Neisser et al (1963) studied the effect of twenty-seven days of practice on multiple target search.

The initial differences between one and ten possible target conditions

was not significant after twelve days of practice. The effect of practice was further demonstrated by Gordon (1968). The effect of ten days of practice on the four types of background resulted in a significant decrease in search time. The decrease in search time was not differential to the conditions.

The question of possible differences in visual search performance due to the age of the subjects was investigated by Gibson and Yonas (1966). Two experimental conditions involved search for one target letter G in two levels of background confusability. The four groups of subjects were selected from Grade two, four, six and University sophmores. The grade differences were significant in both conditions. The significantly faster search times of the older subjects supported the hypothesis that quantitative changes occurred in the cognitive process through development. The lack of significant age by condition interactions failed to support the hypothesis that qualitative changes occurred during development.

Forsman (1967) investigated the effects of target complexity (based on the number of angles within the form) and target form (symmetrical and asymmetrical) on the search performance of three groups of subjects. The subjects were selected from third grade, sixth grade, and university freshmen classes. Increases in chronological age were related to decreases in search time. Complex targets required significantly longer search times than the less complex. This complexity had a greater effect on the younger subjects than on the older subjects. The qualitative difference may, however, be confounded with learning as the subject had

two seconds to view the target before the timing of the search act was initiated.

Visual Search and Retarded Subjects

In reviewing the studies concerned with perceptual processes in mental retardates, Spivack (1963) stressed the need to differentiate between discriminative perceptual processes and perceptual-motor processes. A difference between groups based on a visual search task should not be entirely ascribed to differences in the discriminative perceptual process. In addition, memory and learning factors must be controlled if the study purports to be perceptual in nature.

A study by Rosenberg (1961) compared the performance of two groups of retarded subjects on a visual search task. The range of I.Q.s for the first group was 35 to 37, while the I.Q. range for the second group was 56 to 89. Different nonsense geometric shapes were placed in each cell of a 36 cell matrix. The stimulus (target) was randomly selected from the set of 36 on each trial. The two exposure conditions of the targets prior to each trial were four seconds and continuous exposure. An arbitrary time limit of 60 seconds was given for each trial. The same matrix was used for each trial throughout the experiment. The dependent variables were search time and error scores.

Rosenberg reported that the low I.Q. group was significantly poor on the task under both stimulus exposure conditions. No interactions were significant.

Spivack (1963) questioned the constant presentation of the same

search matrix (visual display). He suggested the presence of an incidental learning situation which would confound the perceptual nature of the task. He also questioned the possibility of a differential effect of the speed set (four seconds).

The discrimination problem in retardates was summarized as follows: "As IQ decreases from average into the retarded range, there is a decrease in efficiency of discrimination between different points along a single stimulus dimension" (Spivack, 1963, p. 488).

A second consideration in the use of a visual search task is the motor response used in physically locating the target. The motor problem in retardates is summarized as follows: "Clinical observations and research studies indicate that the mentally retarded tend to demonstrate less motor competence and skill than do normals of the same sex and age" (Malpass, 1963, p. 626).

Summary

For visual search to take place, the object sought must exist in an environment embodying elements that prevent instant location. The element most applicable to the present study was competition between display items. Display items may compete on several dimensions such as colour, shape, size, and brightness. For example, in multi-coloured displays, prior knowledge of the colour of the target reduced search times.

A common method used in the measurement of visual search performance was search time. This measure was a relatively impure measure of true

search time as it consisted of perceptual-motor as well as discriminative perceptual processes. A purer method of measuring performance was devised by Neisser (1963). This measure of the search rate was unaffected by the initial delay at the onset of the stimulus. However, the use of search rate dictated the necessity of a predetermined search strategy.

Various studies demonstrated the effect of density (number of non-target items) on visual search performance. In general, an increase in density is related to a slowing of the search rate. The search rate was also found to be affected by the background or non-target items. Increased difficulty in discrimination between target and non-target items resulted in increased search rate. In addition, increased homogeneity of background items decreased the search rate.

Eye movement studies during visual search led Enoch (1960) to conclude that the general path of search was controlled by the central nervous system. The eye movements within this general search path were influenced by the effects of peripheral stimulation. The eye movements were influenced to a much greater extent by the display variables than the relatively stable search pattern.

The construction of visual displays used in visual search tasks varied in the degree of organization. Highly structured displays were necessary where search rate was used as a measure of performance. The use of search time permitted a more varied display ranging from matrices to random placement within the boundaries of the display.

Two types of differences could exist when comparing groups on a visual search task: qualitative differences and quantitative differences.

Gibson and Yonas (1966) found a quantitative difference in the cognitive ability with age as measured by a visual search task. The study found no evidence of a qualitative difference in cognitive ability with age.

Spivack (1963) noted that studies comparing groups on some aspect of perceptual processes must endeavour to eliminate perceptual-motor factors, learning factors, and memory factors. This was most important when dealing with groups such as retardates, where obvious differences in these related processes are significant.

# CHAPTER III

## METHODS AND PROCEDURES

The experiment investigated the effects of four experimental conditions on the performance of two groups. The use of two extreme groups in the experiment required the use of test items which minimized any obvious bias to either group. In addition, a target common to the experience of all subjects was required to attempt to control the learning factor.

### Test Items

The target item selected for the experiment was a geometric square (Fig. 1a). The five non target items were closed geometric shapes having approximately the same subjective area as the square (Fig. 1b).

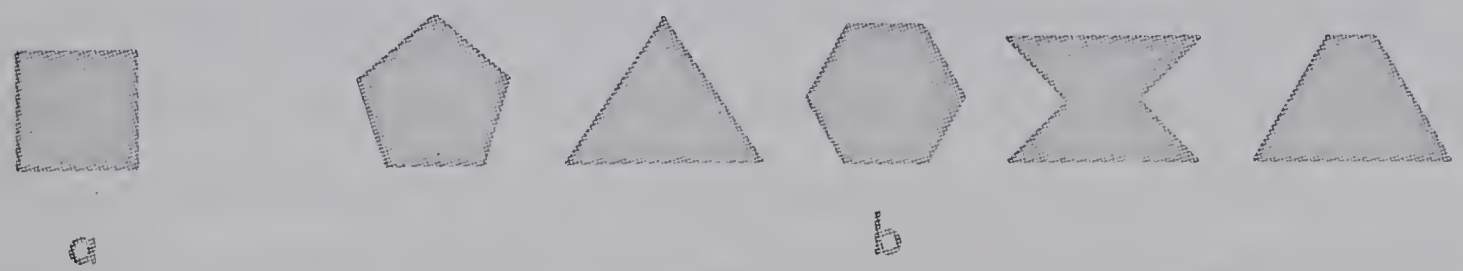


FIGURE 1 VISUAL DISPLAY ITEMS

Subjects

Two groups of eight female subjects each were selected for the experiment. The below average achievement group ($G_B$) was selected on the basis of availability from classes at the Winnifred Stewart School for Retarded Children in Edmonton. The mean chronological age of this group was 9.8 years. Four of the subjects were classified as mongoloids and four were classified as brain damaged.

The subjects comprising the above average achievement group ($G_A$) were selected on the basis of availability from an enrichment class at the Prince Rupert Public School in Edmonton. The mean chronological age of this group was 10.3 years.

Apparatus

The marking pen consisted of a pen cartridge mounted in a copper pen barrel tube (Fig. 2). A micro-switch was mounted on the end of the pen barrel. The pressure created by making a mark with the pen forced the cartridge to depress the micro-switch.

The timing apparatus consisted of eight Standard electric chronoscopes (Model S-1) wired in phase to a stepping relay (Fig. 3). The relay was controlled by the micro-switch mounted on the pen barrel. A second micro-switch (start switch) was wired to the relay and was used by the investigator to start the first clock on each trial. Thus, the time was recorded each time the marking pen was depressed to a maximum of eight times.

A third micro-switch controlled a neon light located on the bank

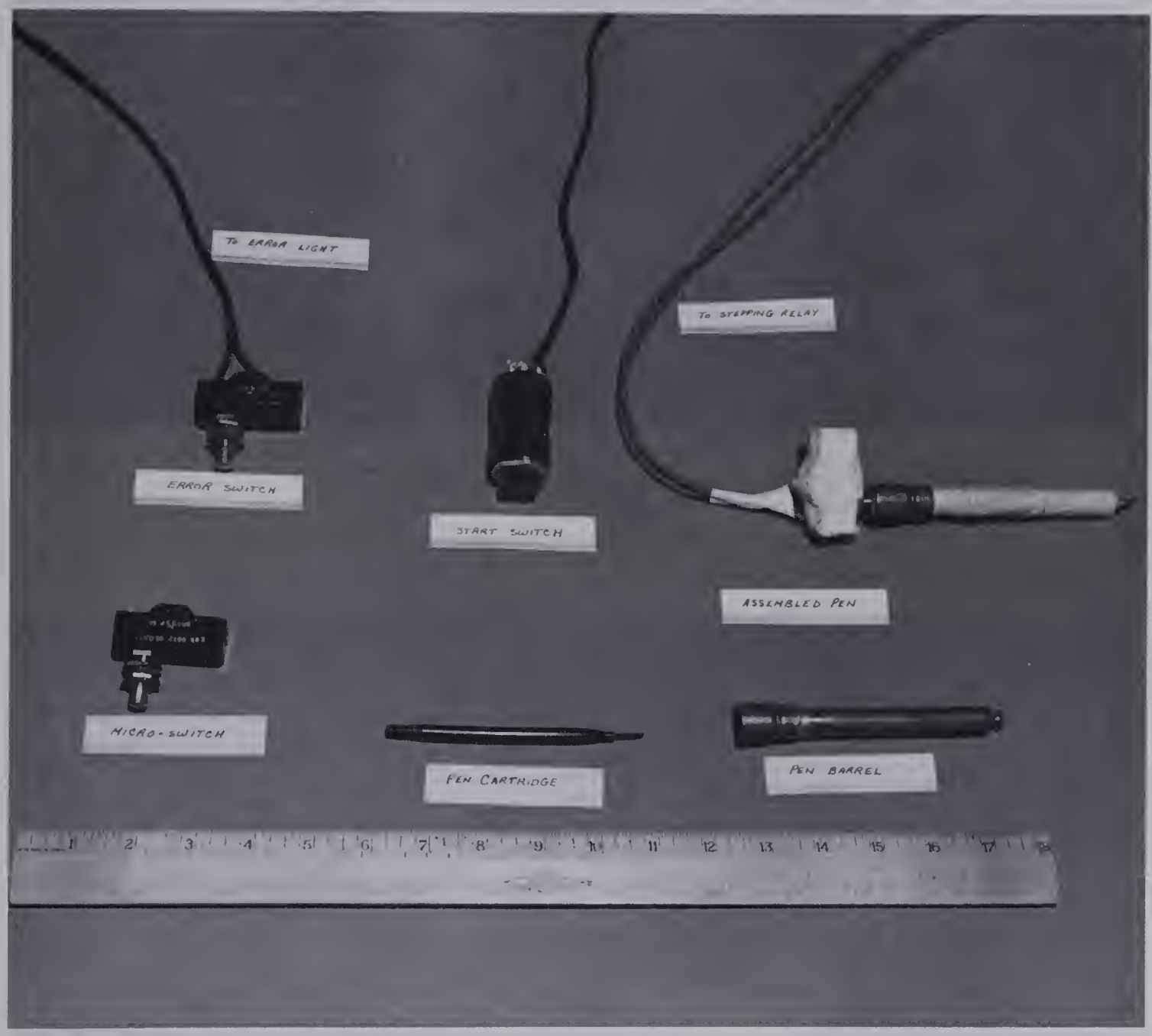


FIGURE 2 MARKING PEN ASSEMBLY

FIGURE 3 TIMING APPARATUS

FIGURE 4 TEST PROCEEDING

of chronoscopes. The light was used to indicate that the subject had made a location error. The location errors were recorded as well as the time required to locate each of the five targets on each trial. The light was controlled by the investigator and was not visible to the subjects.

## Preparation of Treatment Conditions

For each of the four experimental conditions, five trial sheets were prepared. The location of the target and non-target items was determined randomly. In addition, the orientation of each symbol was random. The procedure reduced organizational cues that could have been utilized in the search pattern by some subjects. The size of the target and non-target items was held constant for all trial sheets. The visual search area was also held constant. The packing density for the high density ratio (1:25) conditions was greater than for the low density ratio (1:5) conditions.

Three practice sheets were prepared for each subject. They consisted of a background ratio of 1:5 and density ratios of 1:7, 1:9, and 1:13.

## Procedure

The subject was seated at a table and familiarized with the operation of the marking pen. The subject was instructed to mark each square (target) with the marking pen. A model of the target (square) was mounted on a stand and was present during the course of the experiment

(Fig. 4). The trial sheet was placed between two sheets of white cardboard on the table. The top cardboard was removed and the investigator started the first chronoscope. The subject located as many target items as possible. The trial was terminated upon the successful location of the five target items or when the subject was satisfied that all targets had been located.

Each subject received three practice trials during which time corrections in technique were made by the investigator. Upon completion of the practice trials, any questions concerning the mechanics of the experiment were answered by the investigator.

Prior to the twenty test trials, the subjects were instructed to locate the squares (targets) as quickly and accurately as possible. The experiment was then run to completion with a thirty to sixty second rest period between trials.

## Independent Variables

Three independent variables were selected for the experiment. The first variable was the background (non-target) ratio. A background ratio of one to one represented a condition of similar non-target items. A background ratio of one to five represented a condition employing an equal number of all five non-target items.

The second variable was density, represented by the target to non-target ratio. The two ratios used were one to five and one to twenty-five, representing low and high density conditions.

The third variable was the present achievement level of the subjects.

The presence of a subject in an enrichment class in the Edmonton Public School system was used as the criteria for above average achievement. The presence of a subject in a senior sense training class in the Winnifred Stewart School for the Retarded was used as the criteria for below average achievement.

Dependent Variables

The test instruction allowed each subject to determine their own criteria of speed and accuracy. The following measures were obtained on each of the trials for all subjects.

1. Omission Errors. Target items not located by the subject during the course of a trial.

2. Location Errors. Non-target items marked as target items by the subject.

3. Total Errors. The sum of the omission errors and location errors.

4. Total Time. The sum of the time to locate the five targets.

Two movement times were recorded for each subject. The first movement time consisted of the time required by the subject to mark a square five times, as quickly as possible. The second movement time consisted of the time required by a subject to mark five squares by making a diagonal movement across the trial sheet. The diagonal movement was made five times.

Penalty Times

For trials where omission errors occurred, a time for each of the five targets was not available to assist the analysis, the greatest time required to locate a target under the same experimental condition for that subject was increased by one second and used. The addition of a one second penalty over greatest time was an arbitrary decision.

Experimental Conditions

The two levels of background and density were combined to yield four experimental conditions.

1. Condition one ($C_1$) consisted of a density ratio of one to five and a background ratio of one to one.

2. Condition two ($C_2$) consisted of a density ratio of one to five and a background ratio of one to five.

3. Condition three ($C_3$) consisted of a density ratio of one to twenty-five and a background ratio of one to one.

4. Condition four ($C_4$) consisted of a density ratio of one to twenty-five and a background ratio of one to five.

Experimental Design

The design underlying the experiment was that of a treatment by subjects. Each subject received five trials on each of the four experimental conditions. An identical randomized presentation order was used for each group (Fisher and Yates; 1963, p. 142-3).

Statistical Model

The statistical model used was a two by two by two by five by eight factorial with one entry per cell (Fig. 5).

FIGURE 5

STATISTICAL MODEL

| | | Density Ratio | |
|---|---|---|---|
| | | 1:5 | 1:25 |
| Background Ratio | 1:1 | $G_AG_B$ | $G_AG_B$ |
| | 1:5 | $G_AG_B$ | $G_AG_B$ |

The five trials for each subject under each experimental condition were treated as a replication factor for diagnostic purposes. The eight subjects under each level of achievement were treated as a repetition factor for diagnostic purposes. The model was a complete block with fixed factor levels.

Hypotheses

Hypotheses were formed ad hoc for the main effects of the independent variables. The inclusion of perceptual-motor processes in the measurement of search time biased the test in favour of the above average achievement group.

1. The effect of increasing the achievement groups from below average to above average will result in an increase in total performance.

2. The effect of increasing the density ratio from 1:5 to 1:25 will result in an increase in search time.

3. The effect of increasing the background ratio from one to one to one to five will not cause an increase in search time.

Hypotheses were formed post hoc for the interaction effects of the independent variables. The hypotheses were tested using an alpha level of .01.

# CHAPTER IV

# RESULTS AND DISCUSSION

To adequately explain the effect of the treatment variables (density and background) on the visual search performances of the two groups of subjects, it was necessary to consider the speed and accuracy of the subjects' responses.

## Analysis of the Data

The data was entered and verified on IBM data cards. The data was processed by ANOVA 80, a Fortran IV program for an n way analysis of variance. The analysis was completed on the IBM 360/57 computer at the University of Alberta.

The .01 level of significance was required for the rejection of all *ad hoc* and *post hoc* hypotheses. Sources of variation significant at the .05 level were reported.

A *post hoc* test of means was performed after a significant interaction. The test used was the Newman-Keuls Method.

## Selection of a Measure of Search Time

The use of total time required to locate the five targets on each trial included a large number of penalty times (See Chapter III). The relatively large number of omission errors (Table I) tended to confound the two parameters of performance, speed and accuracy. The time required to locate the first three targets was selected as a measure of search time. It was assumed that the use of this measurement was

representative of the visual search time, while minimizing the effect of omission errors.

TABLE I

FREQUENCY OF TARGET OMISSIONS

| Number of Targets Omitted | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Frequency | 79 | 41 | 19 | 5 | 0 |

Results of the Analysis of Search Time

A three way analysis of variance was performed on the main effects. The results of the analysis are found in Table II. A significant difference was found between the two levels of achievement. The resulting F ratio was 122.39 ($p < .01$). A significant difference was also found between the two levels of density. The F ratio was 133.33 ($p < .01$). The main effect of background was not significant at the .01 level. The F ratio was 4.62 ($.01 < p < .05$).

A post hoc test was applied to the means of each group for the two levels of density. The test used was the Newman-Keuls Method. The effect of density was significant on the search times for both groups (Table III and Table IV).

The mean search times of the two groups for the four treatment conditions are found in Table V.

TABLE II

ANALYSIS OF VARIANCE OF SEARCH TIME (SEC.) BASED ON THE TIME REQUIRED TO LOCATE THREE TARGETS

| Source of Variation | Degrees of Freedom | Mean Square | F Ratio |
|---|---|---|---|
| B (background) | 1 | 1,537.90 | 4.62* |
| D (density) | 1 | 44,427.92 | 133.33** |
| B x D | 1 | 1,178.80 | 3.54 |
| G (achievement group) | 1 | 40,783.90 | 122.39** |
| B x G | 1 | 407.25 | 1.22 |
| D x G | 1 | 17,434.16 | 52.32** |
| B x D x G | 1 | 312.80 | 0.94 |
| Error | 312 | 333.22 | - |

** Critical F Value for df (1,312) at .01 level of significance = 6.73.

* Critical F Value for df (1,312) at .05 level of significance = 3.86.

TABLE III

NEWMAN-KEULS METHOD APPLIED TO THE DIFFERENCE BETWEEN SEARCH MEANS (SEC.) FOR $G_A$ ON TWO DENSITY RATIOS

| Means | Density Ratios 1:5 | 1:25 | Shortest Significant Range |
|---|---|---|---|
| | 3.52 | 12.10 | $R_2$ = 7.63 |
| 3.52 | | 8.58** | |
| 12.10 | | | |

** Significant at the .01 level of confidence.

TABLE IV

NEWMAN-KEULS METHOD APPLIED TO THE DIFFERENCE BETWEEN SEARCH MEANS (SEC.) FOR $G_B$ ON TWO DENSITY RATIOS

| Means | Density Ratios 1:5 | 1:25 | Shortest Significant Range |
|---|---|---|---|
| | 11.11 | 49.44 | $R_2$ = 7.63 |
| 11.11 | | 38.33** | |
| 49.44 | | | |

** Significant at the .01 level of confidence.

TABLE V

MEAN PERFORMANCE TIME (SEC.) FOR FOUR CONDITIONS

| Groups | Condition $C_1$ | $C_2$ | $C_3$ | $C_4$ |
|---|---|---|---|---|
| $G_A$ | 3.61 | 3.43 | 10.10 | 14.09 |
| $G_B$ | 10.70 | 11.52 | 43.21 | 55.67 |

TABLE VI

RESULTS OF TESTS OF SIGNIFICANCE
ON THE POST HOC HYPOTHESES

| Hypotheses | Result of F Test | Probability |
|---|---|---|
| $\theta^2$ bd = 0 | null accepted | 0.06 |
| $\theta^2$ bg = 0 | null accepted | 0.26 |
| $\theta^2$ dg = 0 | null rejected | < 0.01 |
| $\theta$ bdg = 0 | null accepted | 0.33 |

Post hoc hypotheses concerning the interactions resulting from the analysis are summarized in Table VI. The density by groups interaction was significant. The F ratio was 52.32 ($p < .01$). This significant interaction was graphically represented in Figure 6.

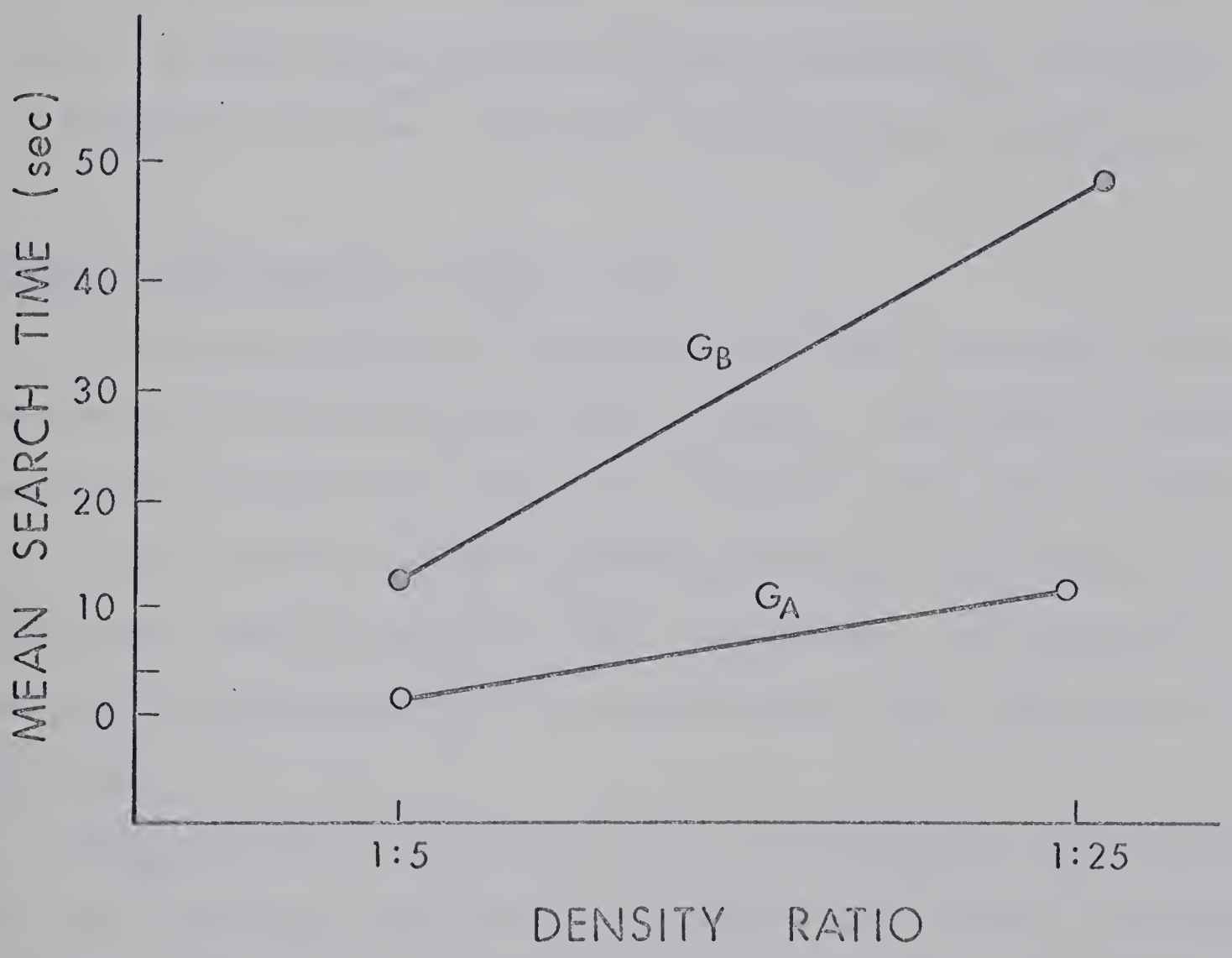


FIGURE 6 DENSITY RATIO vs MEAN SEARCH TIME FOR GROUPS

A five way analysis of variance was performed for diagnostic purposes with respect to replications and subjects. Excerpts were taken from the analysis (Table VII). The table illustrated the replication effect ($F = 3.76$), the subject effect ($F = 10.26$), and the replication by subject interaction ($F = 1.14$). The subject effect was significant at the .01 level. In addition, all sources of variation significant at the .05 level were reported.

The mean search times for each trial of the five trials were reported for each group in Table VIII. Each mean represented 32 search scores. The mean search times and standard deviation for each subject are reported in Table IX. Each mean represented twenty search scores.

Results of the Analysis of Total Errors

A three way analysis of variance was performed on the main effects. The results of the analysis are found in Table X. The effect of achievement level on total error score was significant. The F ratio was 106.80 ($p < .01$). The effect of the two density ratios was significant. The resulting F ratio was 78.33 ($p < .01$). In addition, the effect of the two levels of background ratios was significant. The F ratio was 9.78 ($p < .01$).

A post hoc test was applied to the difference between total errors for each achievement group for the two density ratios (Table XI and XII). The effect of density on total error score was significant for the below average achievement group ($p < .01$). A similar test was applied to the difference between total errors for each achievement group for the two

TABLE VII

EXCERPTS FROM FIVE WAY ANALYSIS OF VARIANCE FOR SEARCH TIME SHOWING F RATIOS SIGNIFICANT AT .01 AND .05 LEVELS

| Source of Variation | Degrees of Freedom | Mean Square | F Ratio |
|---|---|---|---|
| R (replications) | 4 | 733.10 | 3.76* |
| D X R | 4 | 530.28 | 2.72* |
| S (subjects) | 7 | 1,997.95 | 10.26** |
| D X S | 7 | 998.91 | 5.13** |
| G X S | 7 | 1,618.19 | 8.31** |
| D X G X S | 7 | 831.30 | 4.27** |
| R X S | 28 | 221.08 | 1.14 |
| Error | 28 | 194.75 | |

Critical F Values

| df | .05 | .01 |
|---|---|---|
| 4,28 | 2.71 | 4.07 |
| 7,28 | 2.36 | 3.36 |
| 28,28 | 1.88 | 2.47 |

** Significant at .01 level.

* Significant at .05 level.

TABLE VIII

MEAN SEARCH TIMES (SEC.) FOR THE FIVE TRIALS

| Trials | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| $G_A$ | 39.88 | 29.67 | 28.92 | 28.42 | 27.05 |
| $G_B$ | 157.15 | 122.08 | 113.25 | 115.25 | 97.78 |

TABLE IX

MEAN AND STANDARD DEVIATION OF SEARCH TIMES (SEC.) FOR SUBJECTS

| | | | | | |
|---|---|---|---|---|---|
| $G_B$ | Subject | 1 | 2 | 3 | 4 |
| | Mean | 30.73 | 26.20 | 36.93 | 15.55 |
| | SD | 27.50 | 23.38 | 28.54 | 8.74 |
| | Subject | 5 | 6 | 7 | 8 |
| | Mean | 23.61 | 42.55 | 52.69 | 13.95 |
| | SD | 18.33 | 39.31 | 50.01 | 11.55 |
| $G_A$ | Subject | 9 | 10 | 11 | 12 |
| | Mean | 5.60 | 10.20 | 9.24 | 6.66 |
| | SD | 4.74 | 9.40 | 7.80 | 5.01 |
| | Subject | 13 | 14 | 15 | 16 |
| | Mean | 6.72 | 10.06 | 7.15 | 5.94 |
| | SD | 5.65 | 5.63 | 7.31 | 4.36 |

TABLE X

ANALYSIS OF VARIANCE OF TOTAL ERROR SCORES
(OMISSION ERRORS AND LOCATION ERRORS)

| Source of Variation | Degrees of Freedom | Mean Square | F Ratio |
|---|---|---|---|
| B (background) | 1 | 10.88 | 9.78** |
| D (density) | 1 | 87.15 | 78.33** |
| B x D | 1 | 13.20 | 11.87** |
| G (groups) | 1 | 118.83 | 106.80** |
| B x G | 1 | 10.15 | 9.13** |
| D x G | 1 | 81.00 | 72.81** |
| D x D x G | 1 | 12.40 | 11.15** |
| Error | 312 | 1.11 | |

** Critical F value for df (1,312) at .01 level of significance = 6.73.

TABLE XI

NEWMAN-KEULS METHOD APPLIED TO DIFFERENCES BETWEEN TOTAL ERRORS FOR $G_B$ ON TWO DENSITY RATIOS

| Total Errors | Density Ratio 1:5 | 1:25 | Shortest Significant Range |
|---|---|---|---|
| | 17 | 181 | $R_2$ = 35.23 |
| 17 | | 164** | |
| 181 | | | |

** Significant at the .01 level of confidence.

TABLE XII

NEWMAN-KEULS METHOD APPLIED TO DIFFERENCES BETWEEN TOTAL ERRORS FOR $G_A$ ON TWO DENSITY RATIOS

| Total Errors | Density Ratio 1:5 | 1:25 | Shortest Significant Range |
|---|---|---|---|
| | 0 | 3 | $R_2$ = 35.23 |
| 0 | - | 3 | |
| 3 | | | |

background ratios (Table XIII and XIV). The effect of background on total error score was significant for the below average achievement group ($p < .01$). The main effects of density and background was not significant on the total error score of the above average achievement group.

The total errors of each achievement group for the four experimental conditions are presented in Table XV.

Post hoc hypotheses concerning the interactions resulting from the three way analysis of variance are reported in Table XVI. The three first order interactions and one second order interaction were significant at the .01 level. The significant interactions were graphically represented in Figures 7, 8, 9, and 10.

A five way analysis of variance was performed for diagnostic purposes with respect to replications and subjects. Excerpts were taken from the analyses (Table XVII). The table illustrated the replication effect ($F = 0.27$), a subject effect ($F = 2.90$), and the replication by subject interaction ($F = 2.89$). The three effects were not significant at the .01 level.

A further analysis of variance was performed on omission errors. Excerpts from the five way analysis of variance are reported in Appendix A. In addition, a five way analysis of variance was performed on location errors. Excerpts from this analysis are reported in Appendix B.

TABLE XIII

NEWMAN-KEULS METHOD APPLIED TO DIFFERENCES BETWEEN TOTAL ERRORS FOR $G_B$ ON TWO BACKGROUND RATIOS

| Total Errors | Background Ratio 1:1 | 1:5 | Shortest Significant Range |
|---|---|---|---|
| | 70 | 128 | $R_2$ = 35.23 |
| 70 | | 58** | |
| 128 | | | |

** Significant at the .01 level of confidence.

TABLE XIV

NEWMAN-KEULS METHOD APPLIED TO DIFFERENCES BETWEEN TOTAL ERRORS FOR $G_A$ ON TWO BACKGROUND RATIOS

| Total Errors | Background Ratio 1:1 | 1:5 | Shortest Significant Range |
|---|---|---|---|
| | 1 | 2 | $R_2$ = 35.23 |
| 1 | | 1 | |
| 2 | | | |

TABLE XV

TOTAL ERRORS FOR FOUR CONDITIONS

| Groups | Conditions | | | |
|---|---|---|---|---|
| | $C_1$ | $C_2$ | $C_3$ | $C_4$ |
| $G_A$ | 0 | 0 | 1 | 2 |
| $G_B$ | 10 | 7 | 60 | 121 |

TABLE XVI

RESULTS OF TESTS OF SIGNIFICANCE ON
THE POST HOC HYPOTHESES

| Hypotheses | Results of F Test | Probability |
|---|---|---|
| $\theta^2$ bd = 0 | null rejected | < .01 |
| $\theta^2$ bg = 0 | null rejected | < .01 |
| $\theta^2$ dg = 0 | null rejected | < .01 |
| $\theta^2$bdg = 0 | null rejected | < .01 |

TABLE XVII

EXCERPT FROM FIVE WAY ANALYSIS OF VARIANCE FOR TOTAL ERRORS SHOWING F RATIOS SIGNIFICANT AT .01 AND .05 LEVELS

| Source of Variation | Degrees of Freedom | Mean Square | F Ratio |
|---|---|---|---|
| R (replications) | 4 | 0.31 | 0.27 |
| S (subjects) | 7 | 3.29 | 2.90* |
| R x S | 7 | 3.28 | 2.89* |
| Error | 28 | 1.13 | |

Critical F Values

| df | .05 | .01 |
|---|---|---|
| 4,28 | 2.71 | 4.07 |
| 7,28 | 2.36 | 3.36 |

* Significant at .05 level of confidence.

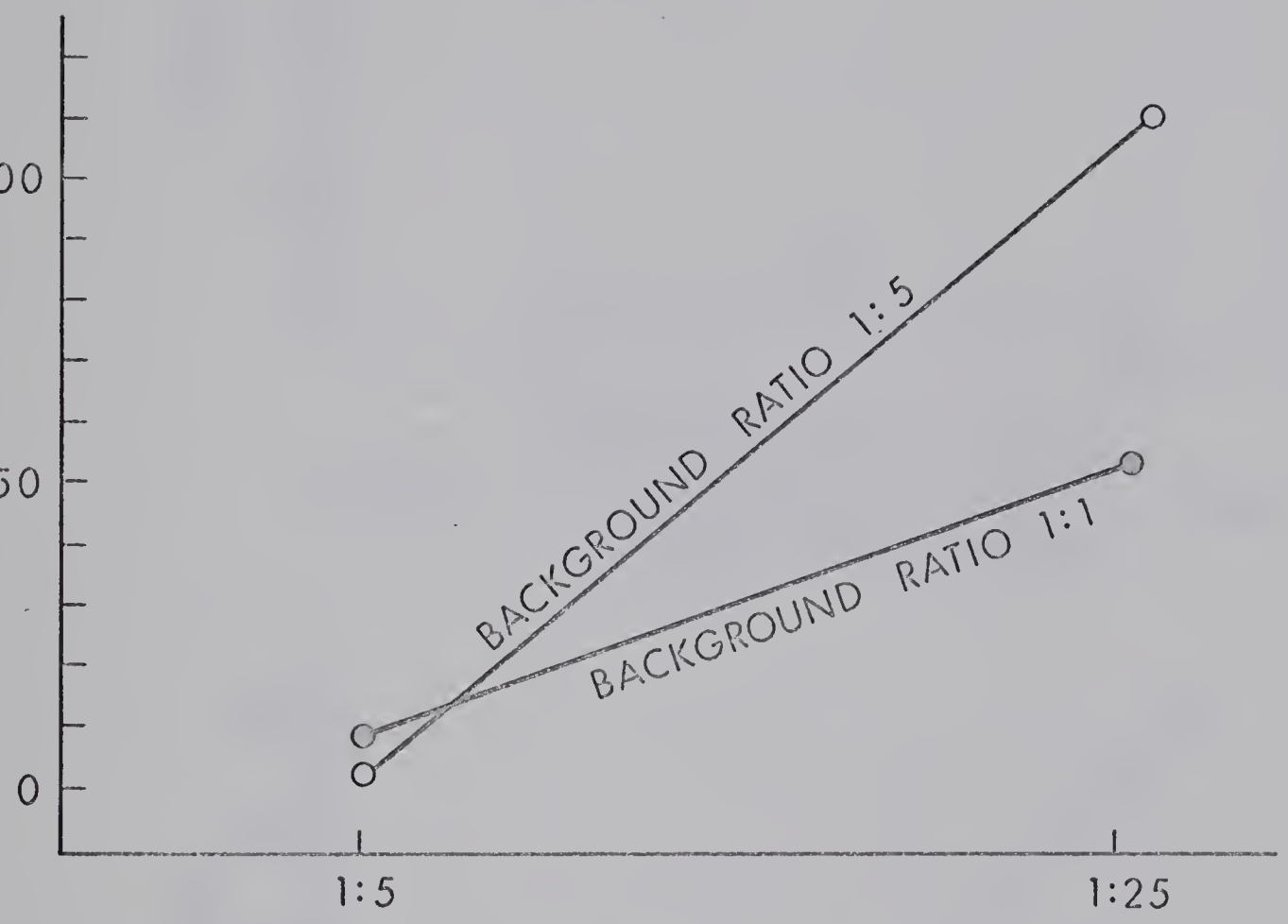


FIGURE 7 DENSITY RATIO vs TOTAL ERRORS FOR BACKGROUNDS

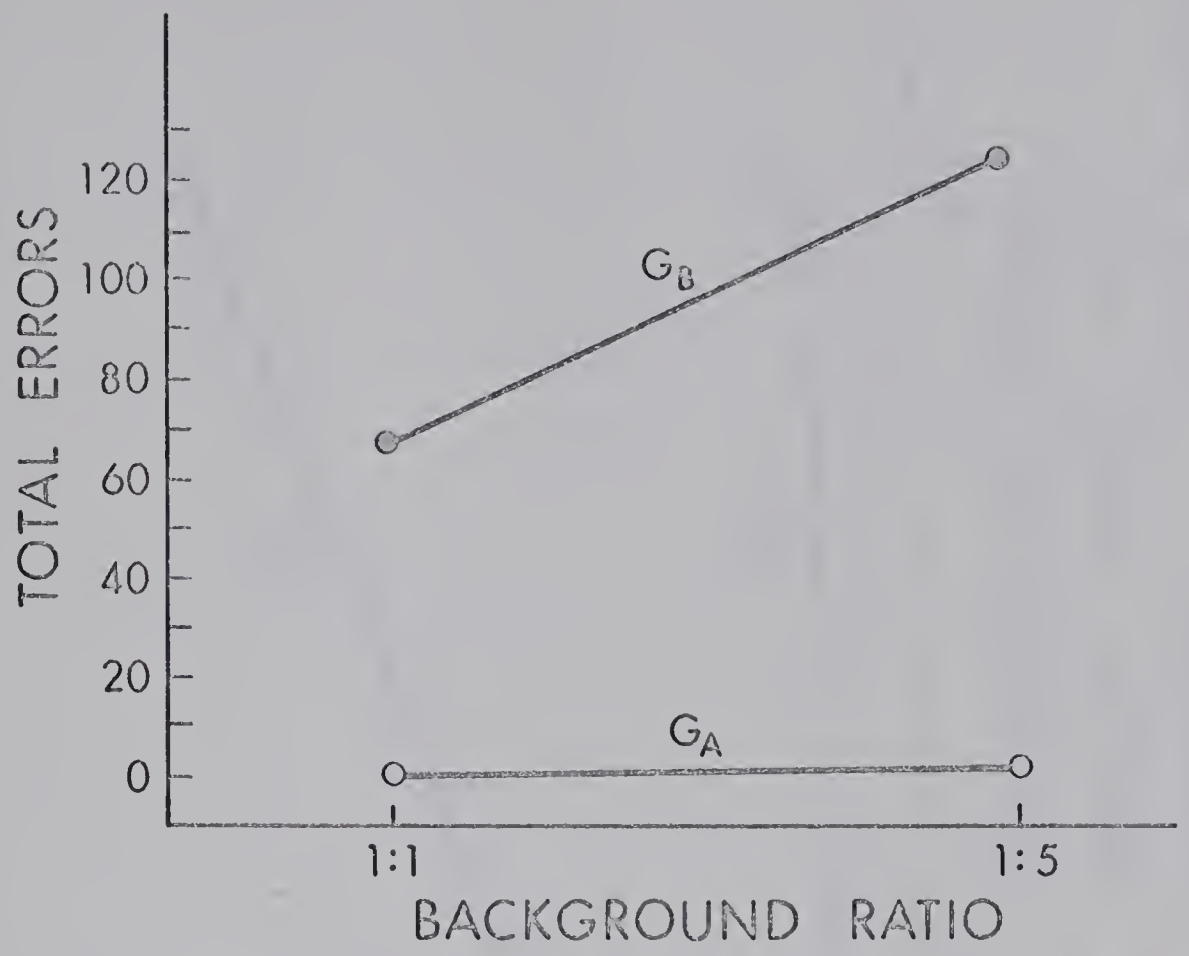


FIGURE 8 BACKGROUND RATIO vs TOTAL ERRORS FOR GROUPS

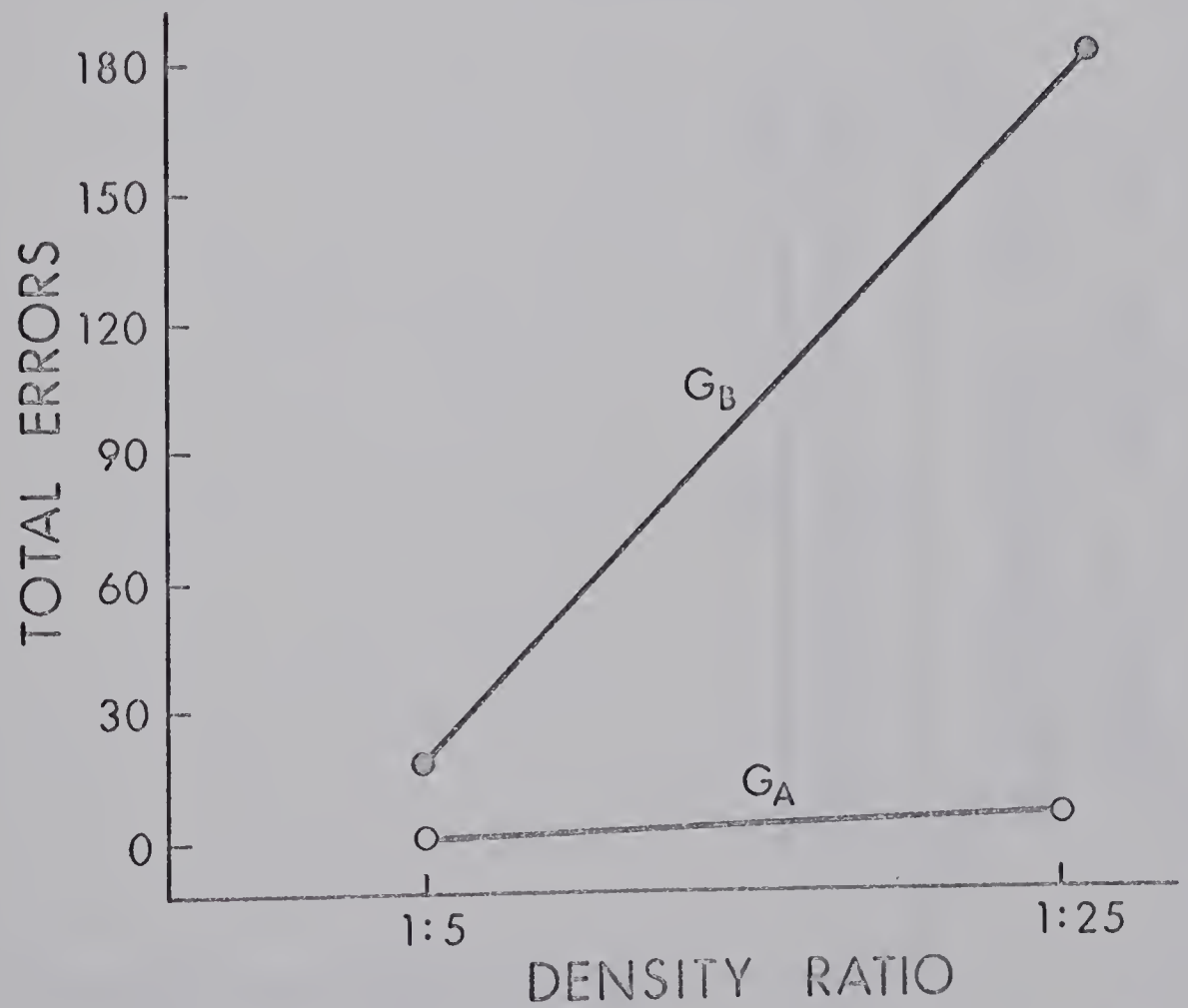


FIGURE 9 DENSITY RATIO vs TOTAL ERRORS FOR GROUPS

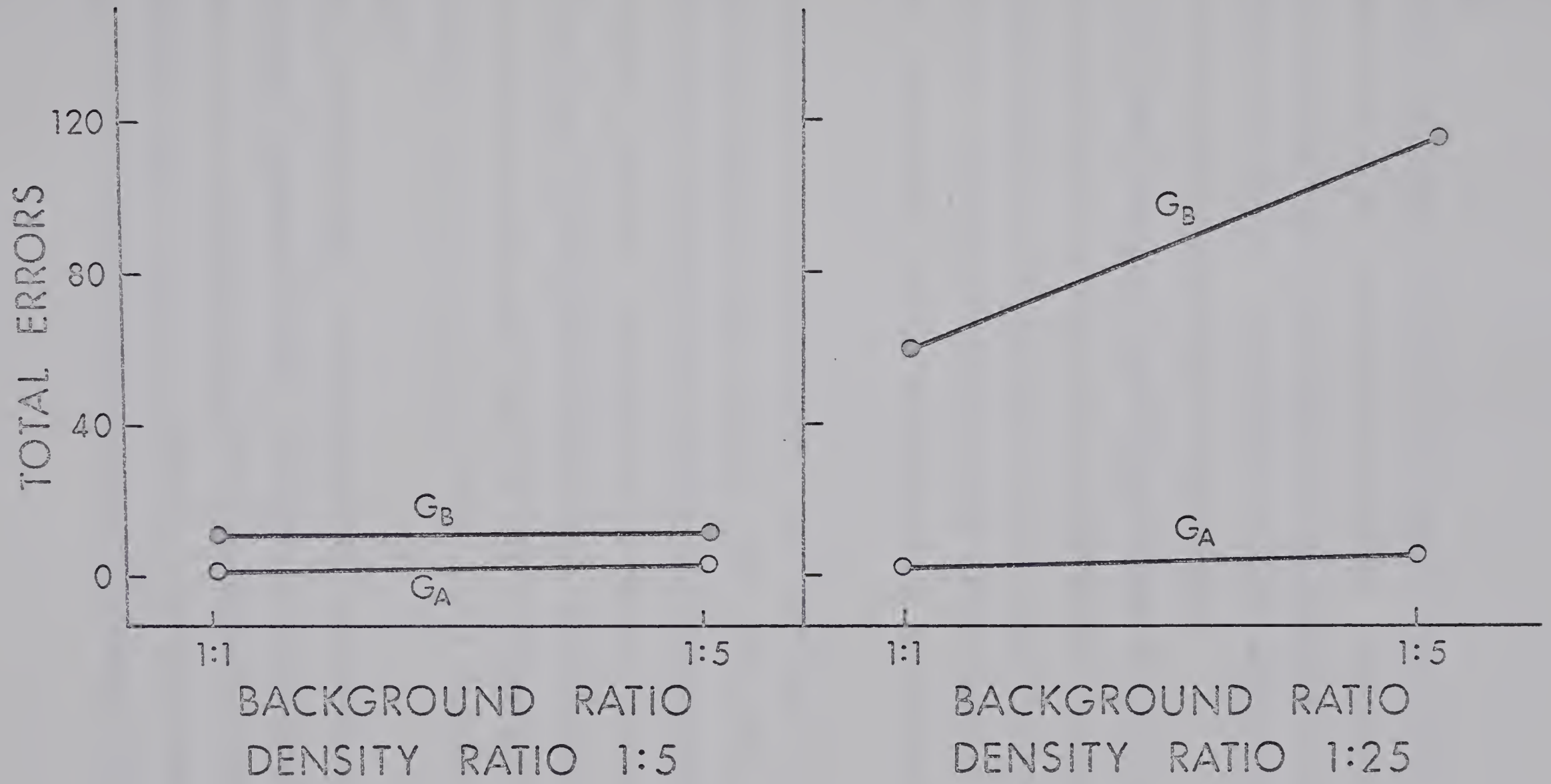


FIGURE 10 INTERACTION FOR DENSITY vs BACKGROUND vs TOTAL ERRORS FOR GROUPS

## Discussion

The visual search test employed in the present study involved visual search strategy and individual eye movements. The lack of organizational cues within the visual display did not present an obvious search method to the subjects. In addition, the test included perceptual motor skills used in the marking of target items.

The significant difference in performance between the two diverse achievement groups was in agreement with the hypothesis formed *ad hoc*. This difference cannot be ascribed solely to the treatment variables used in the test. One important finding was the effectiveness of the test in its applicability to groups differing widely in performance levels.

One premise prior to the experiment was that a performance equivalent to the best expected for each individual could be elicited by the test. All subjects completed the test and many seemed disappointed when the test was completed. One subject in the below average group was given five extra trials before she would leave the test room. The subjective evaluation of the test's applicability to the groups tested was that the test elicited a satisfactory visual search performance from the subjects.

Fitts and Posner (1960, p. 109) suggested that performance may vary on two parameters, speed and accuracy. The above average achievement group demonstrated a significant variation in performance on one of these parameters, speed. The below average achievement group demonstrated variations on both speed and accuracy of performance. Thus speed

(search time) and accuracy (total errors) of visual search performance was analyzed.

The significant effect of density on performance was in agreement with the hypothesis formed ad hoc. McGill (1960) reported an increase in the number of alternatives (non-target items) caused an increase in the search time. The effect of increased density was an increased search time for both achievement groups (Figure 6). A significant increase in total errors occurred for increased density for the below average group (Figure 9). The increased density ratio caused a significant increase in speed and a decrease in accuracy for the below average group.

The effect of background on search time was not significant. This was in agreement with the ad hoc hypothesis. Gordon (1960) found that search rate decreased with increased homogeneity of background. The study by Gordon employed an organized matrix with fixed and constant item orientation. The present study employed random placement and orientation of items. This random deployment of test items may have destroyed the apparent homogeneity of the visual display hypothesized by Gordon to allow longer saccadic eye movements.

The background effect was significant in relation to the total errors committed by the subnormal group (Figure 8). In addition, the effect of background was greater under the high density conditions (Figure 7). The lack of related literature concerned with the specific effect of background on visual search does not allow specific explanations to be discussed at the present time. The effect of background and

density on the accuracy parameter of visual search performance for the two groups was summarized in Figure 9. Increased density caused an increase in the total errors committed by the below average group. In addition, the increase in heterogeneity of background under the higher density condition caused a further increase in total errors.

The order of presentation was random. In addition, the order was replicated for each group. The replication factor was not significant for either search time or total errors. The use of a familiar symbol (square) as the target item may have controlled a possible learning factor.

The significantly greater decrement in the visual search performance of the below average group has been hypothesized as indicative of a limitation of the input component of the below average human performer. The test used involved the subjects general search strategy and the eye movements within this search pattern. As a result the test was not sufficiently definitive to suggest the exact nature of the operational deficiency of the input component. A further revision of the present test, to eliminate the search strategy component may offer a more specific answer to the problem.

# CHAPTER V

# SUMMARY AND CONCLUSIONS

## Summary

The purpose of this exploratory study was to investigate the possible qualitative differences in the visual search performance of above and below average achievement groups. The display variables investigated were density ratio (the ratio of target items to non-target items) and background ratio (the ratio of the form of the non-target item to all other forms of non-target items).

Hypotheses were formed ad hoc for the three main effects. The first hypothesis stated that the effect of increasing the achievement level from below average to above average would result in an increase in search performance. The second hypothesis stated that the effect of increasing the density ratio from 1:5 to 1:25 would result in a decrease in search performance. The third hypothesis stated that increasing the background ratio from 1:1 (homogeneous) to 1:5 (heterogeneous) would not cause a decrease in search performance.

The achievement level group consisted of eight randomly selected subjects from the appropriate educational institutions. Each subject received five trials (replications) under each of the four experimental conditions. The order of treatments was random and the same order was used for each group.

Search performance was investigated from two aspects, speed of response, and accuracy of response. Search performance embodied free-

dom of visual search strategy for each subject.

## Conclusions

The conclusions derived from this exploratory study are only applicable within the limitations of the sample tested and the reliability of the experimental methods and procedures employed. Within this framework, the following conclusions were formulated.

The test employed in the present study was applicable to the widely diverse groups used as subjects. The test items and location techniques employed can be applied to a wide range of subjects differing in achievement levels. The limitations imposed by the starting technique and the timing mechanisms could be eliminated in further studies.

Quantitative differences between the visual search performances of the two groups were significant. These quantitative differences cannot be ascribed in total to the treatment variables used in the present study. Perceptual motor factors were present in the execution of the test. These factors had a differential effect on the performance of the two groups.

Performance on the visual search task showed variation along two performance parameters, speed and accuracy. The above average group exhibited significant changes in the speed parameter. No significant change was found in the accuracy of this group under the experimental conditions. The below average group exhibited significant changes in both speed and accuracy. An increase in display density caused a significant decrease in the search performance of this group. The decrease

in total performance was increased by an increase in total errors. These findings support the hypothesis that qualitative differences exist between achievement level groups on a visual performance task.

## Further Direction

The finding of qualitative differences in visual search performance of the two diverse achievement level groups leads to many subsequent questions. The use of one or more intermediate levels of each of the three experimental variables (density, background, achievement level) would provide a more comprehensive description of the relationships involved.

The present study was restricted to the use of a static visual display. In most activities within the scope of Physical Education, the visual display or environment is dynamic rather than static. It would appear that studies constructed to investigate the visual search behaviour of performers on a dynamic search task would be beneficial to the eventual development of curricula for specific groups.

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# APPENDIX A

EXCERPTS FROM FIVE WAY ANALYSIS OF VARIANCE OF OMISSION ERRORS SHOWING F RATIOS SIGNIFICANT AT THE .01 AND .05 LEVELS

| Source of Variation | Degrees of Freedom | Mean Square | F Ratio |
|---|---|---|---|
| B (background) | 1 | 1.95 | 8.07** |
| D (density) | 1 | 47.28 | 195.39** |
| B x D | 1 | 2.63 | 10.86** |
| G (groups) | 1 | 62.13 | 256.77** |
| B x G | 1 | 2.28 | 9.42** |
| D x G | 1 | 45.75 | 189.09** |
| B x D x G | 1 | 3.00 | 12.41** |
| R (replications) | 4 | 0.15 | 0.63 |
| S (subjects) | 7 | 1.30 | 5.36** |
| D x S | 7 | 0.84 | 3.48** |
| G x S | 7 | 1.25 | 5.16** |
| D x G x S | 7 | 0.82 | 3.38** |
| Error | 28 | 0.24 | |

Critical F Values

| df | .05 | .01 |
|---|---|---|
| 1,28 | 4.20 | 7.64 |
| 4,28 | 2.71 | 4.07 |
| 7,28 | 2.36 | 3.36 |

** Significant at the .01 level of confidence.

# APPENDIX B

EXCERPTS FROM FIVE WAY ANALYSIS OF VARIANCE OF LOCATION ERRORS SHOWING F RATIOS SIGNIFICANT AT THE .01 AND .05 LEVELS

| Source of Variation | Degrees of Freedom | Mean Square | F Ratio |
|---|---|---|---|
| B (background) | 1 | 3.61 | 5.59* |
| D (density) | 1 | 6.05 | 9.37** |
| B x D | 1 | 4.05 | 6.27* |
| G (groups) | 1 | 9.11 | 14.11** |
| B x G | 1 | 2.81 | 4.35* |
| D x G | 1 | 5.00 | 7.74** |
| B x D x G | 1 | 3.20 | 4.95* |
| R (replications) | 4 | 0.19 | 0.31 |
| S (subjects) | 7 | 2.51 | 3.89** |
| B x S | 7 | 1.71 | 2.65* |
| B x D x S | 7 | 2.16 | 3.35* |
| G x S | 7 | 2.31 | 3.58** |
| B x G x S | 7 | 1.54 | 2.39* |
| B x D x G x S | 7 | 1.94 | 3.01* |
| Error | 28 | 0.65 | |

Critical F Values

| df | .05 | .01 |
|---|---|---|
| 1,28 | 4.20 | 7.64 |
| 4,28 | 2.71 | 4.07 |
| 7,28 | 2.36 | 3.36 |

** Significant at .01 level of confidence.
* Significant at .05 level of confidence.